ANALYSIS OF DISPLACEMENTS AND DEFORMATIONS FOR A SLUDGE FERMENTATION TANK (RFN4) OF THE WASTEWATER TREATMENT PLANT GLINA

Aurel SĂRĂCIN, Associate Professor Ph.D., Faculty of Geodesy, Technical University of Civil Engineering Bucharest, saracinaurel@yahoo.com
Constantin COSARCA, Associate Professor Ph.D., Faculty of Geodesy, Technical University of Civil Engineering Bucharest, constantin_cosarca@yahoo.com
Adrian SAVU, University Lecturer Ph.D., Faculty of Geodesy, Technical University of Civil Engineering Bucharest, adisavu2002@yahoo.com
Aurel NEGRILA, Teaching Assistant Ph.D., Faculty of Geodesy, Technical University of Civil Engineering Bucharest, negrila.aurel@gmail.com

Abstract: *After a process of monitoring an ovoid tank (RFN4) when it is emptied and then filled, you can make predictions of elastic deformation of the concrete structure can be estimated vulnerable zones and cracking of concrete. Are shown evolutions of rigidly fixed targets in characteristic points of reinforced concrete structure at different levels, for different degrees of filling of an ovoid tank, useful engineers building structures for we confirm strength calculations with finite element models.*

1. General considerations

Monitoring of special construction, especially in the process of rapid change of the internal stress state, and stress and relative to the foundation soil, requires a specific design of the reference system, of procedures and achievement of an appropriate program of observations.

Through good cooperation and communication with the client work, Glina wastewater treatment plant, it could process captures the relevant RFN4 emptying the tank in 4 steps, after extraction of approx. 2000 m^3, 4000 m^3, 6000 m^3 and 8000 m^3 of mud, until the tank was empty, in February-March 2013.

For RFN4 tank, based on geotechnical and structural analysis, was performed a bottom drain of the product in the tank, these operations of RFN4 rehabilitation ending in late August 2013, when they started operations for loading the sample with water to the tank. Thus, we conducted a phase measured when the tank was still empty stage will be considered as a first step to monitor deformation during filling process of the RFN4.

With three-dimensional positions of points which constitute the reference and points on the monitored object RFN4, observations were made for the analysis of reference network stability and observations necessary to determine the displacements and strains studied points materialized on the object RFN4, into 4 stages during the filling process, 1/4, 1/2, 3/4 and after complete filling, respectively pumping of volume corresponding to 2000 m^3, 4000 m^3, 6000 m^3 and 8000 m^3 of water into RFN4 tank, in September-October 2013.

Design and implementation of the reference network envisaged the possibility of monitoring all containers RFN (figure 1), but this time the theme of this work is to study only RFN4 (figure 2), for which they were stationed only observation points were interested in the subject monitored targets.

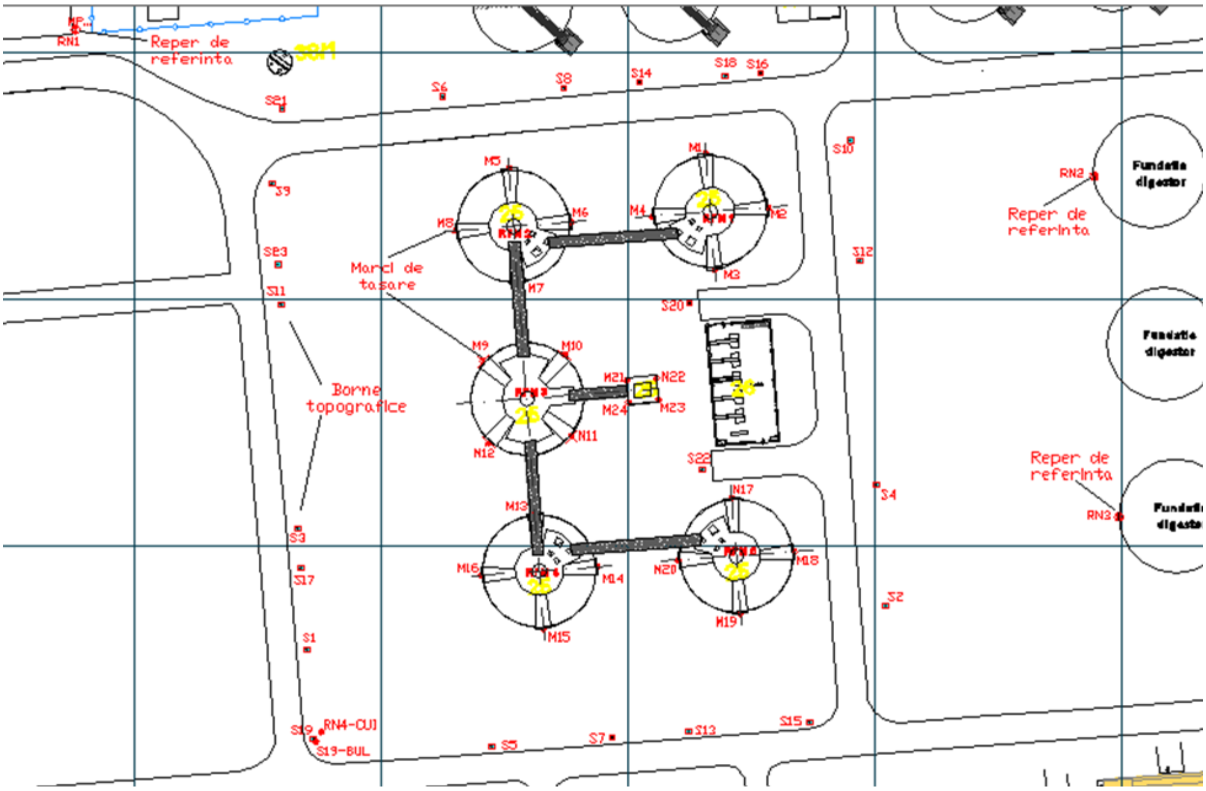

Fig. 1. Tracking network for RFN tanks park.

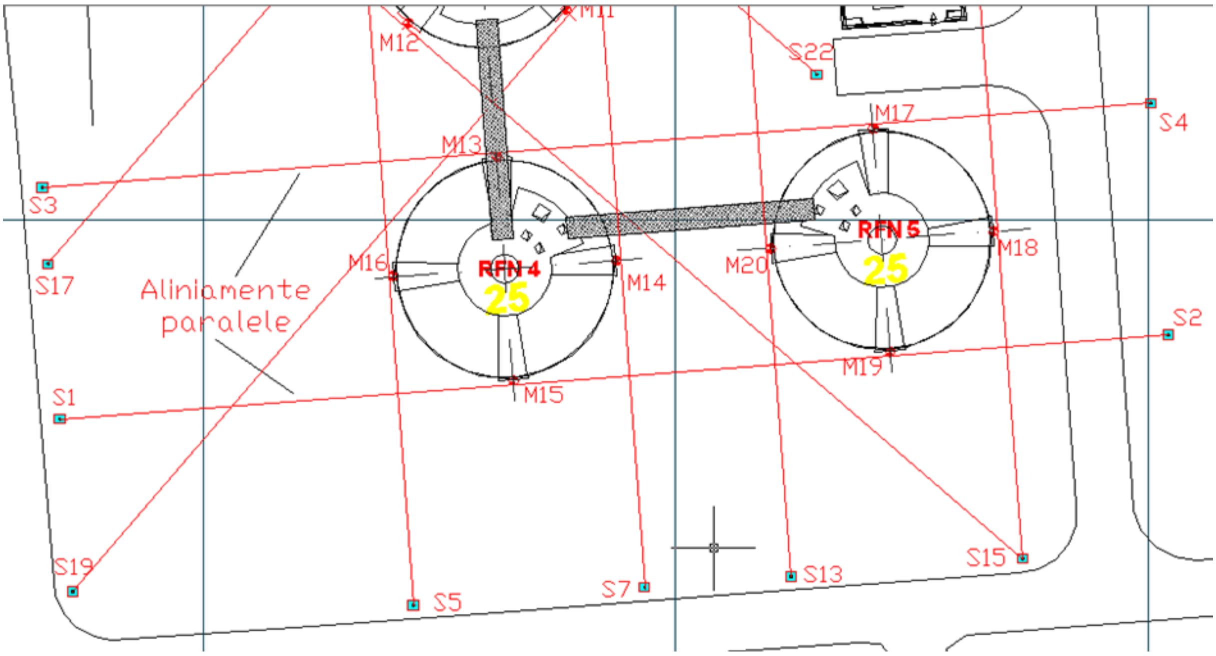

Fig. 2. Tracking network of the RFN4 tank area.

2. Interpretation of altimetric observations

The degree of filling of RFN4 tank during the draining and filling process highlights the foundation soil reaction and influence on neighboring tanks. Therefor were made the observations of geometric precision leveling on routes that included 4 the settlement marks of RFN4, and by two the settlement marks on RFN3 and RFN5, those located at RFN4. These routes (geometric leveling traverses) are based on reference elevation marks RN1, RN2 and RN3 (figure 3).

Fig. 3. Reference elevation marks.

Evolution of the vertical displacement from the initial stage can be seen in the table below and the diagrams in figures 4 and 5.

Table 1.

Objectiv	Mark	Settlement (mm) from Stage (Et.) 0									
		Et.1	Et.2	Et.3	Et.4	Et.5	Et.6	Et.7	Et.8	Et.9	Et.10
RFN3	M11	0.3	0.0	0.8	1.2	1.0	1.0	0.3	0.2	-0.2	0.4
	M12	0.1	0.2	0.9	1.0	0.3	0.8	0.4	0.1	-0.5	0.0
RFN4	M13	1.0	2.2	4.4	6.6	5.9	7.0	5.5	4.0	1.6	0.5
	M14	0.9	2.2	4.1	6.3	6.0	6.8	5.6	3.8	1.6	0.5
	M15	1.1	2.7	4.8	6.8	6.8	7.5	6.3	4.2	2.0	0.6
	M16	1.2	2.7	4.9	7.1	6.9	7.9	6.3	4.4	1.7	0.6
RFN5	M19	-0.2	0.0	0.2	0.5	0.3	0.1	0.3	0.0	-0.1	0.3
	M20	0.1	-0.1	0.5	1.0	0.7	0.7	0.5	0.2	-0.1	0.2

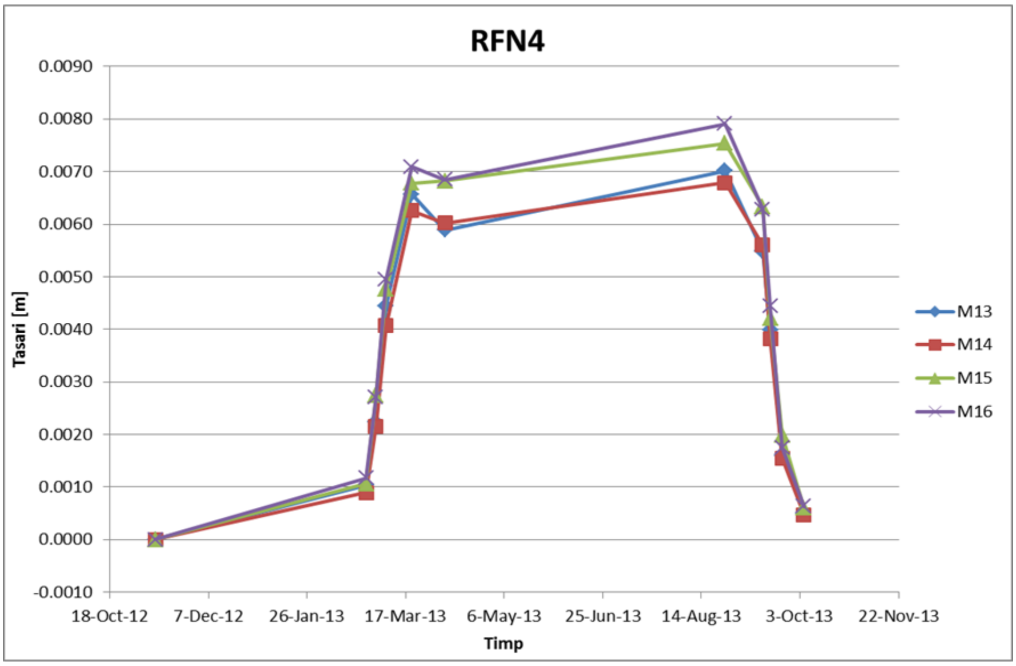

Fig. 4.

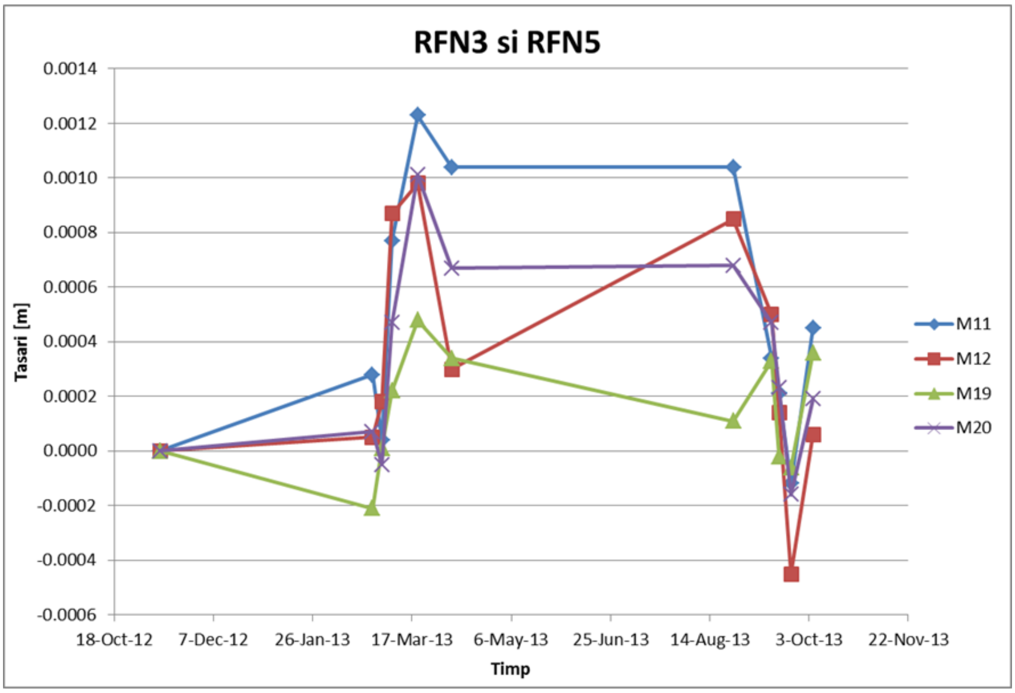

Fig. 5.

It can be observed an uniform lifting approx. 7 mm of RFN4 in the process of emptying, after a settlement of around 7 mm uniform all in the process of filling, influencing neighboring tanks with lifting and settlements within +/- 1 mm.

3. Interpretation of the monitoring spatial observations

From the point of view of deformation, the area of greatest interest of the monitoring observations is median ovoid, the targets of the median (denoted M13M, M14M, M15M and M16M) have revealed changes in diameter oval shaped tank.

From M13M and M15M coordinates can be calculated diameter in the X direction of the local coordinate system and the coordinates M14M and M16M can calculate the diameter in the Y direction of the local coordinate system, in the middle of RFN4, with relations:

$$D_{M13M-M15M} = \sqrt{(X_{M15M} - X_{M13M})^2 + (Y_{M15M} - Y_{M13M})^2} \text{-1 m}$$
$$D_{M14M-M16M} = \sqrt{(X_{M14M} - X_{M16M})^2 + (Y_{M14M} - Y_{M16M})^2} \text{-1 m}$$

The "-1 m" is the aggregate length of the two rods of stainless steel (target-of-sight in the middle) arranged diametrically opposite each having a length of 0.5 m

This diameters, determined in this manner, could be compared from one observation to the next stage, can be observed oval deformation in the emptying (steps 1-4) and the filling process (steps 7-10).

Calculation of diameters in the median area RFN4

Table 2.

	Et. 0	Et. 1	Et. 2	Et. 3	Et. 4	Et. 6	Et. 7	Et. 8	Et. 9	Et. 10
$D_{13\text{-}15}$	23.8279	23.8222	23.8200	23.8171	23.8215	23.8239	23.8291	23.8268	23.8247	23.8291
$D_{14\text{-}16}$	23.8524	23.8447	23.8452	23.8464	23.8445	23.8433	23.8404	23.8425	23.8392	23.8431

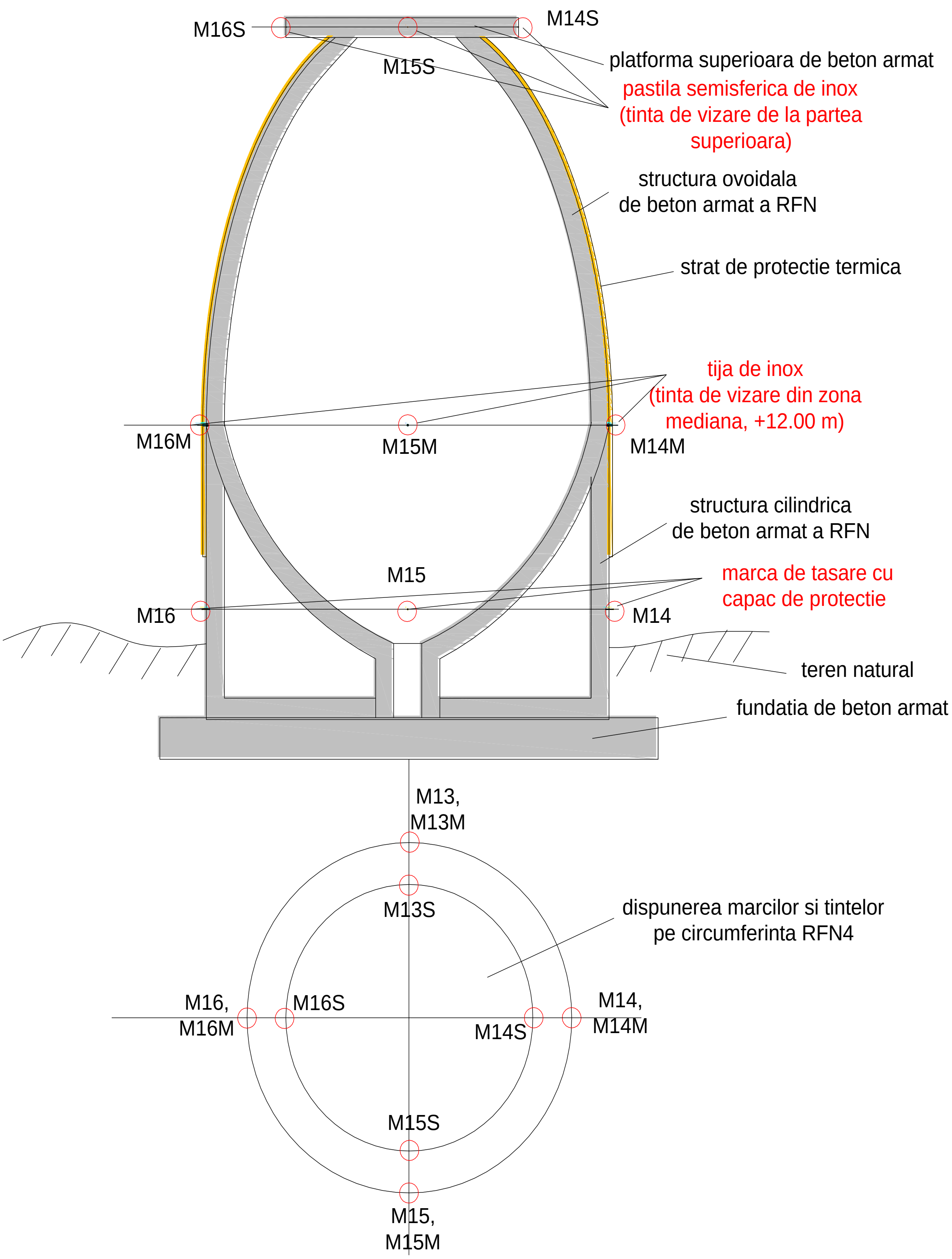

Fig. 6.

The object point coordinates were determined by multiple spatial intersections, relative to the tracking network, from measurements made with the total station Leica TPS 1202.

In the initial stage were obtained spatial coordinates of the object points, those in the table below.

Inventory of coordinates and elevations
Monitored object: RFN 4 - Stage 0
Projection plane: LOCAL
Reference system: LOCAL

Table 3.

Point name	**COORDINATES (m)**		**HEIGHTS (m)**	**STANDARD DEVIATIONS (mm)**		
	X	**Y**	**H**	**S_X**	**S_Y**	**S_H**
M13S	50039.7071	9947.5619	101.6459	3.2	2.2	2.8
M13M	50047.0694	9947.6514	78.0396	1.3	2.0	1.3
M13	50046.8400	9947.6565	70.3753	1.3	2.0	1.3
M14S	50034.7286	9952.8072	101.5730	1.5	2.4	2.6
M14M	50034.6234	9960.0433	77.9348	1.6	1.9	1.2
M14	50034.6389	9959.7809	70.4035	1.6	2.0	1.1
M15S	50029.5980	9947.7883	101.5653	1.8	1.0	2.1
M15M	50022.2416	9947.5922	77.5524	1.3	0.8	0.8
M15	50022.4975	9947.6245	70.4098	1.3	0.9	0.7
M16S	50034.6338	9942.6388	101.5718	1.3	2.9	2.6
M16M	50034.5859	9935.1909	78.0392	1.0	2.3	1.1
M16	50034.6756	9935.4523	70.4165	1.2	2.4	1.1

In each round of observations were followed the same procedures, obtaining three-dimensional coordinates corresponding standard deviations of the same order of magnitude. In the tables below are shown only coordinate differences, grouped separately that during in the emptying process and that during the filling process (in this case the reference stage was 6 stage of measurements).

Table 4.

Punct obiect	**Diferente (mm) Et. 1 – Et. 0**			**Diferente (mm) Et. 2 – Et. 0**			**Diferente (mm) Et. 3 – Et. 0**			**Diferente (mm) Et. 4 – Et. 0**		
	dX	**dY**	**dH**	**dX**	**dY**	**dH**	**dX**	**dY**	**dH**	**dX**	**dY**	**dH**
M13M	1.9	-1.6	-10.1	0.8	-3.7	-7.5	-1.8	-3.5	-5.8	2.9	-3.2	-0.9
M14M	4.8	-0.7	2.8	2.5	-0.2	4.6	1.9	-0.4	6.7	2.9	-0.2	8.8
M15M	7.5	1.9	-8.7	8.6	1.9	-7.5	8.9	2.2	-6.0	9.2	2.0	-0.1
M16M	4.0	7.0	2.2	3.5	7.0	2.7	1.7	5.7	2.0	1.6	7.7	6.6

Table 5.

Punct obiect	**Diferente (mm) Et. 7 – Et. 6**			**Diferente (mm) Et. 8 – Et. 6**			**Diferente (mm) Et. 9 – Et. 6**			**Diferente (mm) Et. 10 – Et. 6**		
	dX	**dY**	**dH**	**dX**	**dY**	**dH**	**dX**	**dY**	**dH**	**dX**	**dY**	**dH**
M13M	5.5	-3.5	-2.5	2.6	-2.6	-4.0	-1.1	-1.2	-8.6	4.6	-4.1	-10.1
M14M	-0.4	-0.8	0.2	-1.2	0.0	-1.5	-0.8	-2.3	-4.5	0.3	1.5	-11.3
M15M	0.3	-0.2	0.4	-0.2	0.0	1.0	-1.8	3.4	-5.9	-0.6	0.5	-13.8
M16M	-1.0	2.1	-0.1	-0.4	0.7	-3.0	5.0	1.8	-8.1	-1.3	1.7	-11.7

Comparing the X and Y coordinates of these targets in the median, from one stage to another, graphical representations can be made in the following way:

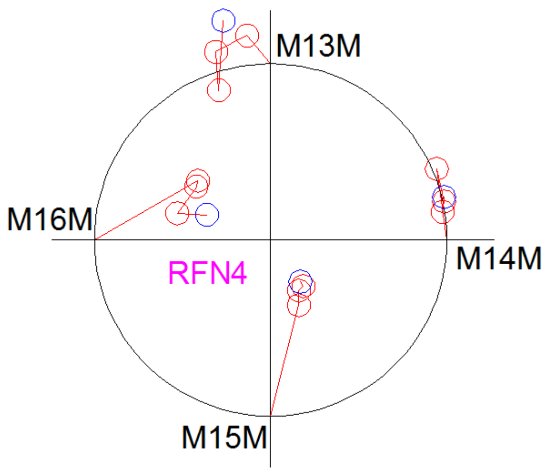

Fig. 7. The emptying process.

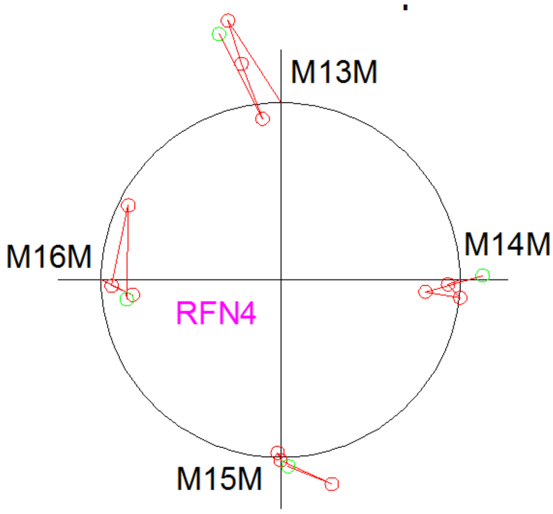

Fig. 8. The filling process.

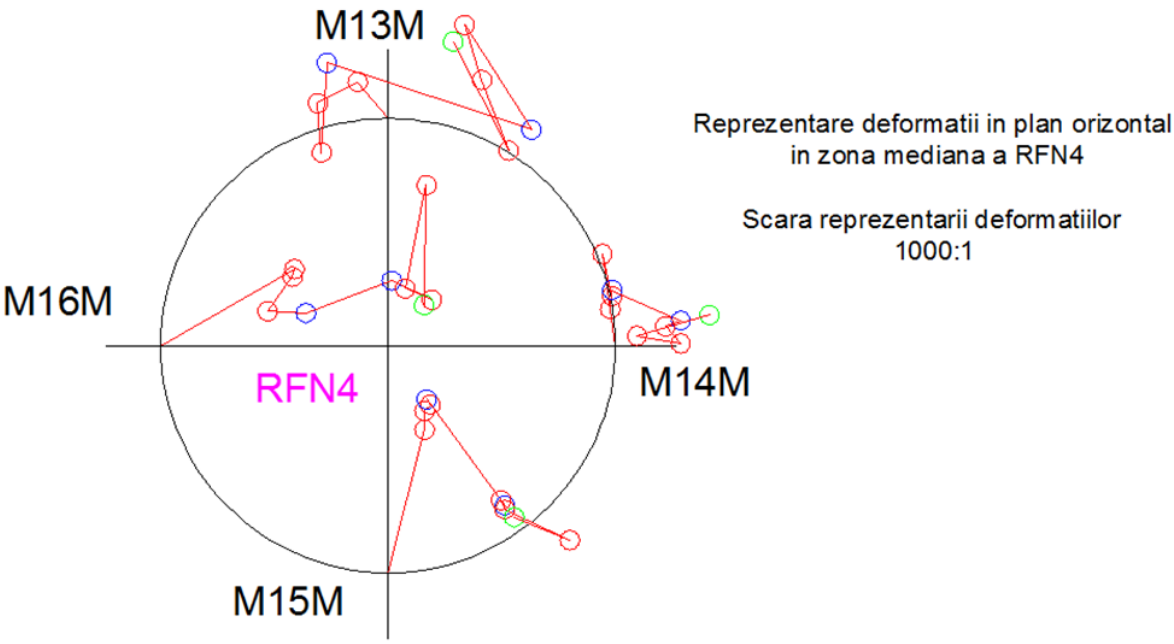

Fig. 9.

In this representation includes all phases of observations, are indicated by blue steps on the end of the emptying and the beginning of the filling process, and in green, end of the filling process.

Vertical evolution of these targets can be played back the following graphs:

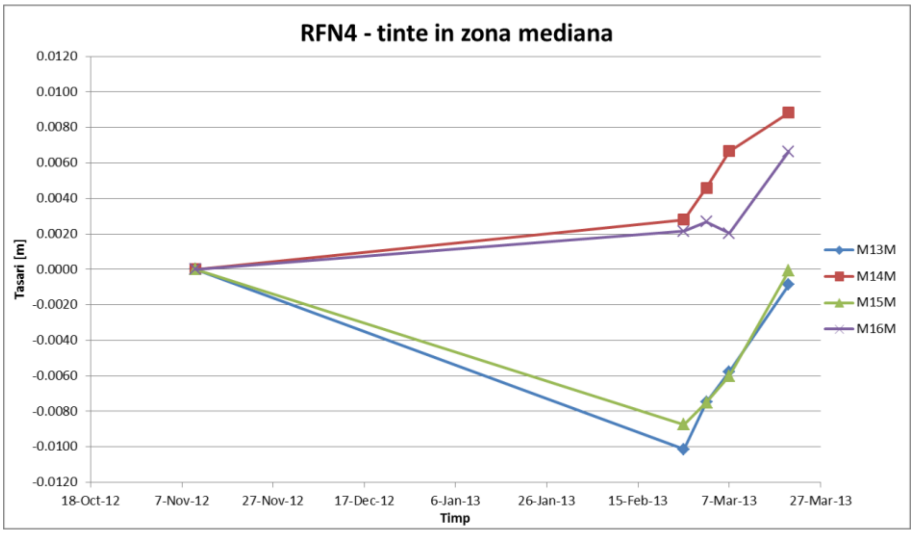

Fig. 10. The emptying process.

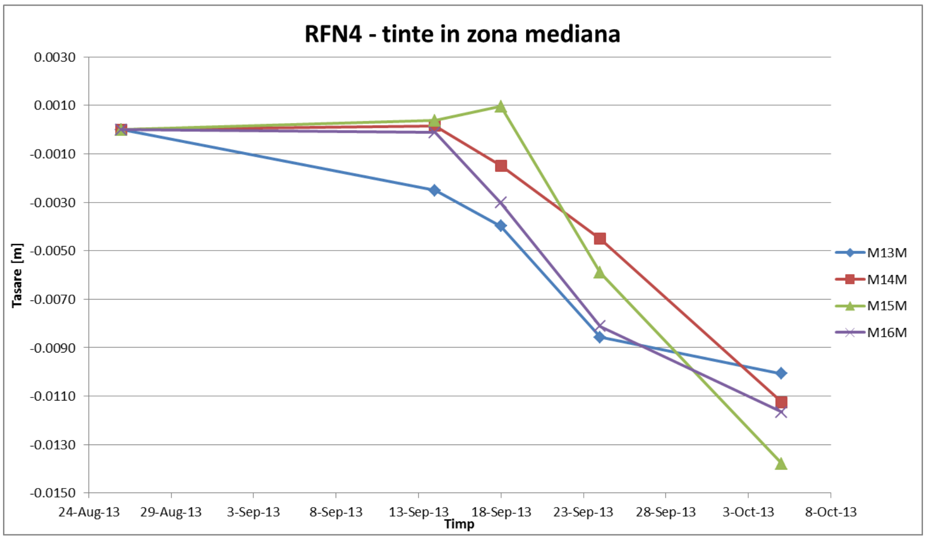

Fig. 11. The filling process.

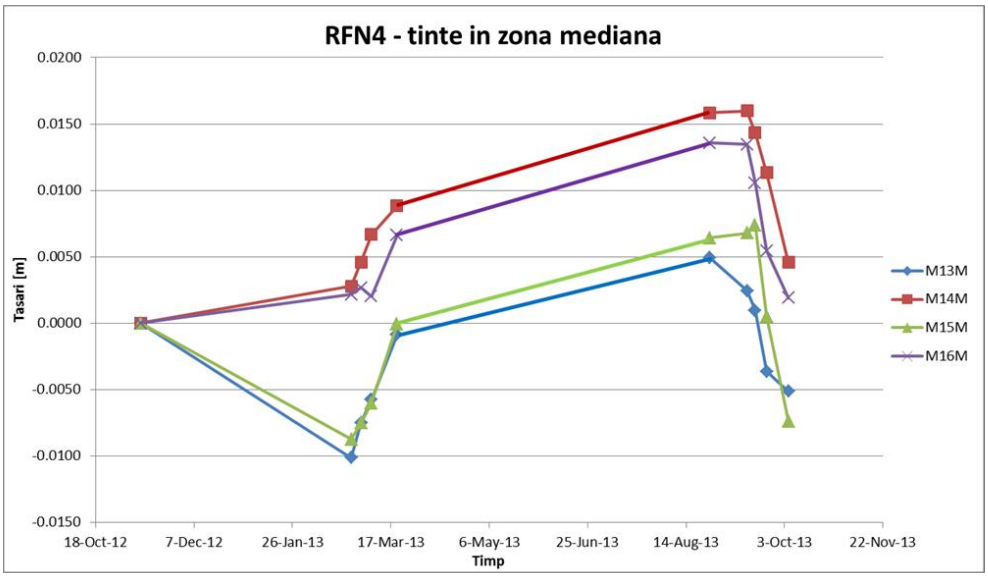

Fig. 12. The representation of both processes, emptying and filling.

For the points materialized at the top of RFN4, on the reinforced concrete cap, an amplified graphical representation of the movements and deformations, using the coordinate values of the initial stage, to the end of the emptying (red), from the beginning of the filling (with blue) and the last stage at the end of the filling process (green), can be as follows:

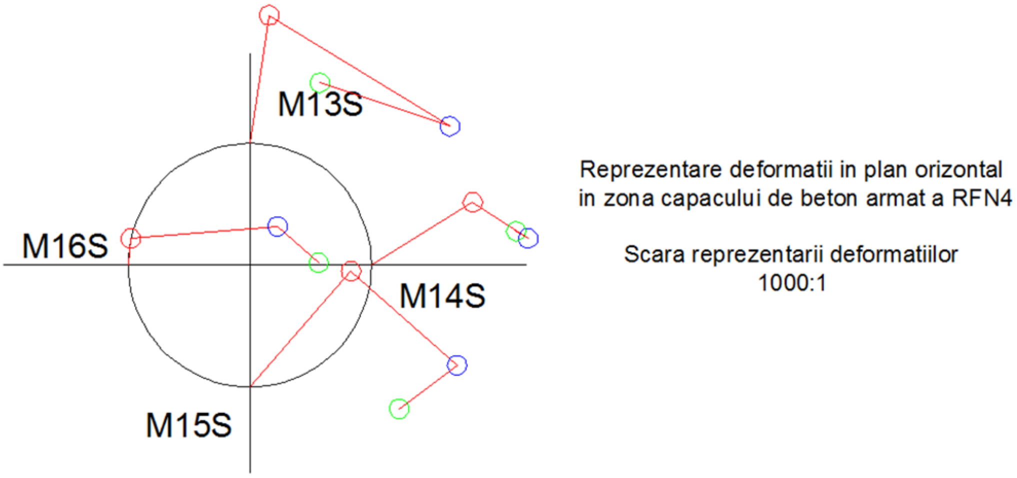

Fig. 13.

Differences values of three-dimensional coordinate mentioned in above steps from the initial stage are shown in the table below.

Table 6.

Object points	Differences (mm) Et. 4 – Et. 0			Differences (mm) Et. 7 – Et. 6			Differences (mm) Et. 10 – Et. 6		
	dX	dY	dH	dX	dY	dH	dX	dY	dH
M13S	5.3	0.8	-6.0	4.8	-3.6	-4.2	1.8	-5.4	-14.7
M14S	2.6	4.2	-5.4	0.8	-1.2	-0.1	0.3	-0.5	-17.3
M15S	4.8	4.2	-5.8	0.2	-1.3	-0.8	-1.8	-2.4	-16.9
M16S	1.1	0.1	-11.2	0.1	1.4	-1.5	-1.5	1.7	-13.9

If we compare the heights values (H) of targets at the top of the RFN4, the heights trigonometric determined, will be able to obtain a graphical representation of the below form.

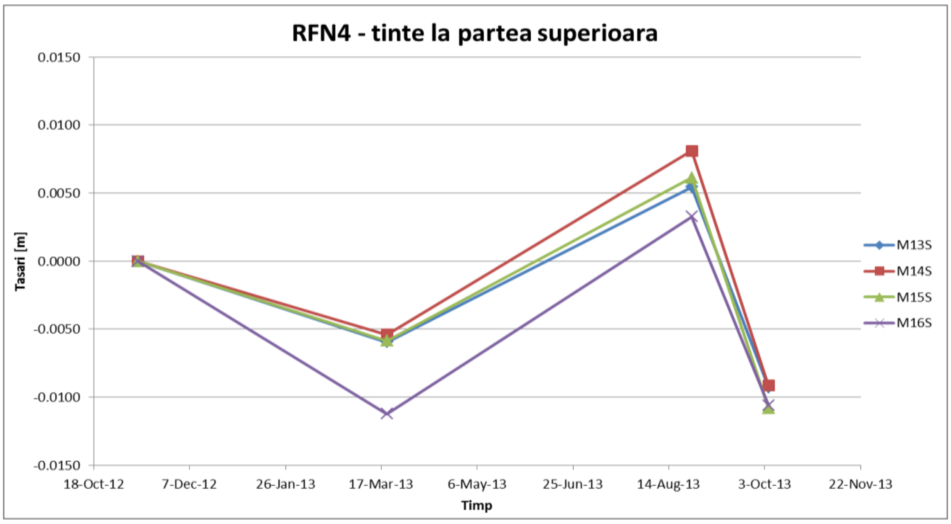

Fig. 14.

4. Conclusions

The results confirmed a good choice to design a geodetic network solution to determine coordinates and heights of characteristic points evidenced on the monitored construction RFN4.

High precision equipment used during the measurements allowed to obtain three-dimensional positions of the object points in the precisions required.

Processing of observations was made using algorithms and performance programs which provided an opportunity to estimate and correct interpretation of measurement results.

In all stages of the observations were used the same methods and tools, with redundant measurements to allow verification and confirmation of the correctness of the results.

They could notify the vertical uniform movements (lifting and settlements) of the RFN4 tank, in distinctly for the emptying process and that in the process of filling.

The ovoid shape deformation of the RFN4 tank, could be highlighted particularly noting the evolution of three-dimensional coordinates of the target in the middle area of the tank, which coordinates gave an overview of changing ovoid diameter, and the complex three-dimensional deformation, given the particular type of tank structure, a relatively supple and elastic structure.